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2. Patent application number *(The Patent Office will fill in this part)* — 0220899.9 — -9 SEP 2002

3. Full name, address and postcode of the or of each applicant (*underline all surnames*) — **The University of Liverpool,** Senate House, Abercromby Square, Liverpool, L69 3BX

   Patents ADP number (*if you know it*) — 7736630001

   If the applicant is a corporate body, give the country/state of its incorporation — ENGLAND.

4. Title of the invention — AUTOMATION SYSTEM FOR INFORMATION MANAGEMENT, CONDITION MONITORING AND REAL-TIME CONTROL OF DISTRIBUTED INDUSTRIAL SYSTEMS.

5. Name of your agent (*if you have one*) — **W.P.THOMPSON & CO.**

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* — Coopers Building, Church Street, Liverpool, L1 3AB.

   Patents ADP number *(if you know it)* — 0000158001

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Country	Priority application number *(if you know it)*	Date of filing *(Day/month/year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(Day/month/year)*

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Description	12
Claims(s)	
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11. I/We request the grant of a patent on the basis of this application

Signature Date 9th Sept 2002

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DESCRIPTION

AUTOMATION SYSTEM FOR INFORMATION MANAGEMENT, CONDITION MONITORING AND REAL-TIME CONTROL OF DISTRIBUTED INDUSTRIAL SYSTEMS

The present invention relates to industrial automation systems and is concerned in particular with a system intended for integrated information management, condition monitoring and real-time control of distributed industrial systems using the Internet, computer network and software agent technologies.

Most industrial automation systems are based on the SCADA methodology, in which a central server monitors and controls a large number of devices. However, these systems provide limited flexibility, and often do not integrate well with other systems.

A conventional automation system used for control of an industrial plant consists of sensors connected to the plant, data acquisition devices, interface racks, actuators, cables and wires for transmission of analogue quantities, microprocessor-based controllers and a platform for operator intervention. The controllers, that are required to operate on-line in real-time, are usually connected to plant equipment through relatively short-length cables, wires or optical fibres, designed with consideration of signal distortion, noise interference and cable reliability. Therefore, the controllers are distributively installed within a limited distance in the plant and if there are large numbers of pieces of plant that undertake a variety of tasks within

different time scales then the controllers are generally uncoordinated. For a complex industrial plant, such as a power system substation, chemical plant or steel manufacturer, it is difficult to connect various pieces of equipment, data acquisition devices, interface racks, actuators and controllers to central platforms and it is impossible in practice to network these items horizontally and vertically within a hierarchic structure. The network would be very complex, as a huge number of cables and wires are used for a variety of purposes. Various items within the substation, such as control systems, protection systems, quality of supply monitors, condition monitoring equipment etc., collectively known as IEDs (intelligent electronic devices) would be networked together. There may be 50 IEDs of varying complexity at a large substation and there are 250 substations in England and Wales. Therefore, the task of developing and using such a complex and continually changing network is not simple. Due to the complexity of most industrial systems, the conventional automation system can only undertake simple tasks and it is not capable of providing the required information management, condition monitoring and real-time control functions simultaneously and intelligent coordination between system devices.

In accordance with the present invention there is provided an automation system comprising a plurality of software agents adapted to implement specific functions used for information management, condition monitoring and real-time control.

Advantageously, these agents, and preferably all of the agents in the system,

are controlled and managed by agent platforms and local directories.

An agent is a program able to perceive and react to changes in its environment. It is capable of acting in an autonomous and goal-directed manner, so that the actions of an agent are not caused only by inputs from the environment, but by the goals or desires of the agent. This is in contrast to a standard computer program, whose actions are determined only by direct manipulation (e.g. clicking on icons) by users or commands from other programs. Therefore agent-based architectures can be much more flexible than standard architectures.

Preferably, an automation system in accordance with the present invention includes a plurality of different types of software agent.

Software agents that can be used in a system in accordance with the invention include Information Retrieval Agents, Wrapper Agents, Data Transportation Agents Information Management Agents, Knowledge Agents, and Control Agents, supported by multi-agents technology.

Mobile agents can also be embedded in the system.

A mobile agent is a program able to transport itself from one place to another and continue its execution. This means that the mobile agents can run small programs of their own directly on a target location. By using mobile agents, the information recovered can be geared directly to the type of user, displaying only the relevant information in the format most suited to the user type. Hence different types of mobile agents will normally be used. These mobile agents could have the ability of being active. The use of multi-agent technology can greatly enhance development

of distributed databases, designed in association with various tasks implemented in WAN and different LANs, respectively.

Advantageously, the architecture of the present system makes use of standard, currently available technology, including the FIPA standards for agent platforms. All current publicly available FIPA platforms are based on Java. The control agents and user interface agents are intended to be resident on devices and to perform real-time tasks. In this case, Java is not a preferred choice for implementation of these agents due to its memory and processor requirements. The user interface agent must integrate with existing HMI and user interface packages. For this task, Active X controls are often a suitable option.

The simplest way to integrate agents written in different languages and on a variety of systems is to use a sockets-based protocol (TCP or UDP). However, because there is no available FIPA platform currently available that supports such a protocol, a gateway is used to translate messages between this protocol and the Java objects used to transfer ACL messages within the FIPA platform.

Preferably, the system has an open standard architecture and clearly defined protocols and interfaces, adapted to allow integration of a variety of software and hardware.

Preferably, at least some of the system components can be re-configured dynamically.

Preferably, the system includes comprehensive HMIs and a web browser and provides real-time operator intervention.

Advantageously, use is made of commercial real-time application platforms, such as Lookout, Automation X and RTAP as HMIs.

Preferably, the system allows connections of mobile servers.

Preferably, the system is adapted to embed user applications of information management, condition monitoring and real-time control flexibility.

Advantageously, the system is arranged to posses the potential of adding intelligent behaviour using different agent models and embedding intelligent approaches to plant operation and control problems.

Advantageously, the system is adapted to provide an integration of information management, condition monitoring and real-time control functions for various devices distributed over LANs and WAN.

Preferably, the system is adapted to be able to handle different types of tasks in different time scales required for the information management, condition monitoring and real-time control of large-scale distributed industrial systems.

Advantageously, the system has potential to be applied for small and large industrial systems.

Systems in accordance with the invention can be built out of many local and small components with greater flexibility.

Thus, in contrast to conventional automation systems, a system in accordance with the present invention (usually referred to by us as an e - Automation system) can provide integrated functionalities for distributed information management, intelligent monitoring and real-time control with an open architecture of IP networks for

implementation of various tasks within Wide Area Networks (WAN), Local Area Networks (LAN) and wireless LANs. RGE system will be able to provide great gridability and communication capability to resolve the problems of task implementation and information management for a wide range of distributed industrial systems such as power plant, power utility, railways, manufacture and chemical plants, and medical care etc., using network and multi-agent technologies, with intelligence embedded in the system network and software structures.

A system in accordance with the present invention can be designed to implement various tasks such as Data acquisition, Data transportation, Database updating, Knowledge base updating, Information management, Information retrieval, Network computing, Dynamic display, Real-time control and Operator intervention, etc. These tasks may have a different nature and are conducted at different time scales over WAN and LAN. The implementation of these tasks requires support of various protocols, which may be developed using different software languages and standards such as C, Java, XML, TCP/IP, CORBA, RDF, SQL, Active X etc. The protocols development work is undertaken according to the IEC, FIPA and IEEE standards.

Further advantages which can be acquired by systems in accordance with the invention include:

a) system can be built out of many small components - giving greater flexibility;

b) system capable of dynamic re-configuration - components can be

added and removed while the system is running;

c) the system is distributed - information and control is local rather than central;

d) loose coupling between components - adds robustness;

e) can be open system - standard, clearly defined protocols and interfaces allow integration of a variety of software and hardware; and

f) it is possible to add intelligent behaviour using different agent models.

This invention thus introduces a concept of e-Automation, which defines a new generation of automation systems for information management condition monitoring and real-time control of a wide range of distributed industrial systems, with the integration of the latest network and agent technologies. It provides an open architecture with software intelligence and system coordination embedded for the design and development of large-scale distributed industrial automation systems.

At a first level, various agents are introduced to provide an integrated approach to the information management, condition monitoring and real-time control of industrial systems.

At a second level, an open architecture of the system is designed specifically for development of various distributed industrial automation systems.

At a third level, an agents platform and a local directory are developed for control and management of the multiple agents online in real-time.

At a fourth level, the interfaces and protocols conversions between agents, Human-Machine interfaces, data sockets, to enable the integration of all functions

provided the e-Automation system. This development is represented by computer code.

The invention is described further hereinafter, by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is a diagrammatic illustration of one possible embodiment of an automation system in accordance with the present invention; and

Fig. 2 illustrates the architecture of an automation system embodying the invention.

Fig. 1 shows a system involving three local area networks (LANs) responsive to I P networks for information management, intelligent monitoring and real-time control of a plurality of industrial systems, such as factories, power stations, and hospitals, and integrated by a single wide area network (WAN).

For an understanding of the architecture of the system of Fig. 2 having WAN, LANs and wireless LANs, reference is directed to the following list of possible system components:

AP: Agent platform, A server or set of servers on which agents can execute. The AP provides messaging and directory facilities for the agents.

A CL: FIPA Agent Communication Language. A standard language used for communication between software agents.

App. A: Application Agent. These agents perform tasks such as knowledge management, alarm/event handling etc., depending on the needs of particular locations or applications.

CA: Control (device) Agent. This agent controls a device.

DB: Database.

DBA: Database Agent. This agent allows others to query the real-time database.

DocA: Document Agent. This agent provides access to a document collection.

DTA: Data Transport Agent. This agent acquires data from the IEDs and stores it into the real-time database. This is an additional functionality to the database agent, which allows only database queries. This task is not performed by the control agents in order to reduce the load on these agents. If data transport functionality is provided by the IEDs, SCADA or HMI system, this agent is not required. The DTA may either be resident on the agent platform or outside (on the diagram it is shown inside the AP).

FIPA: Foundation for intelligent Physical Agents. A standards organisation for multi-agent systems.

GUI: Graphical User Interface.

HMI: Human-Machine Interface.

HTTP: Hypertext Transfer Protocol. The protocol used for transmitting Web pages.

IED: Intelligent Electronic Device. A control or monitoring device containing an embedded processor.

IP: Internet used for network packet delivery on the Internet. IP is normally

used in combination with TCP or UDP.

IPMT: Internal Platform Message Transport. An acronym used by FIPA to denote whatever transport protocol is used for message transport within a FIPA platform. Many FIPA platforms use |Java RMI as the IPMT.

JDBC: Java Database Connectivity.

LAN, WAN: Local Area Network, Wide Area Network.

Local directories. The local directories are used to assist agents in locating each other. Agents that provide a service register with a directory. Client agents (the user agent, mobile agents and possibly other agents) can then use the directory to locate services that match their requirements. The DF (Directory Facilitator) is a standard component of a FIPA agent platform, and provides such a directory service.

DF: Directory Facititor.

MA, MA Host mobile Agent, Mobile Agent Host.

Mobile Server: A server that is temporarily added to the system in order to provide some specific functionality, for example, the detailed monitoring of an item plant.

MSA: Mobile Server Agent. Either a database agent or control agent (some mobile servers may have both of these) responsible for providing access to the resource of a mobile server.

MTP: Message Transport Protocol. There are a number of message transport protocols that may be used for inter-platform communications, e.g., IIOP,

HTTP.

Message Proxy and Platform Locations translates from a non-standard format, such as ACL over TCP/IP, to a standard format used by an agent platform. It is also possible to build in service location features to allow agents to locate the nearest platform within a local area network.

OPC: OLE for Process Control.

SCADA: Supervisory Control and Data Acquisition system. Used for control and monitoring of many industrial systems.

SOL: Structured Query Language. A standard language for performing database queries.

SSL: Secure Sockets Layer. A protocol used on the Internet for encryption of online transactions. Based on public key cryptography.

TCP: Transport Control Protocol. A connection-oriented network protocol which provides reliable message delivery.

UA: User Agent.

UDP: User Datagram Protocol. A connectionless network protocol that is faster, but less reliable, than TCP.

WWW: World Wide Web.

Why are some agent outside the AP?

Some agents are outside the AP. The idea behind the architecture is to make use of standard, currently available technology, including the FIPA standards for agent platforms. All current publicly available FIPA platforms are based on Java.

Therefore, agents implemented using other languages such as C++ can not run on these platforms' servers.

Problems with this are encounted in relation to the control agents and user interface agents. The control agents are intended to be resident on devices and to perform real-time tasks. Therefore, Java is currently a poor choice for implementation of these agents due to its memory and processor requirements. The user interface agent must integrate with existing HMI and user interface packages. For this task, Active X controls are often a suitable option, but these cannot be implemented using standard Java.

The simplest way to integrate agents written in different languages and on a variety of systems is to use a sockets-based protocol (TCP or UDP). However, because there is no publicly available FIPA platform that supports such a protocol, a gateway is used to translate message between this protocol and the Java objects used to transfer ACL messages within the FIPA platform. The agents outside the AP are able to communicate with those agents managed by the AP

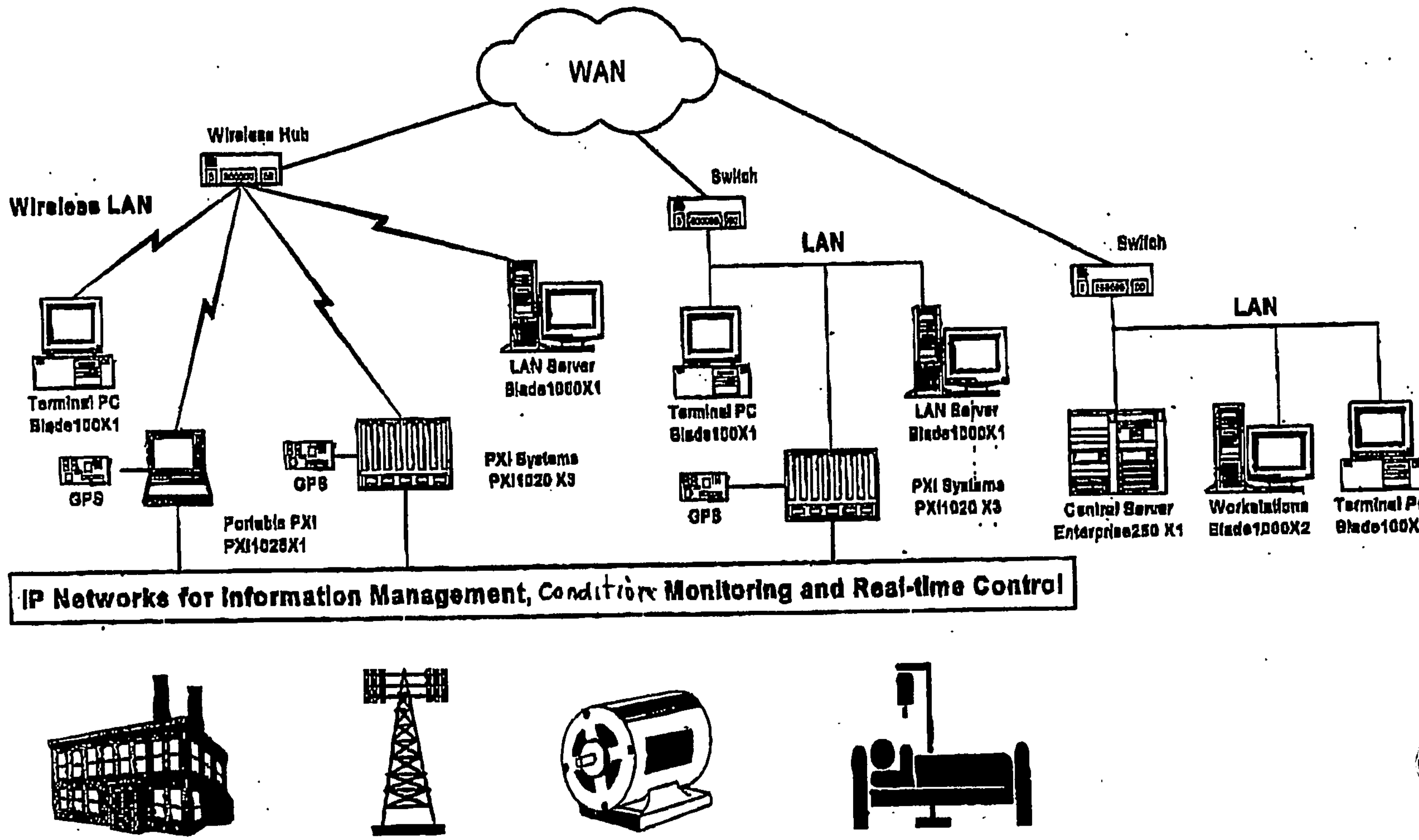
WAN
Wireless Hub
Wireless LAN
Switch
LAN
Switch
LAN
Terminal PC
Blade100X1
GPS
Portable PXI
PXI1025X1
GPS
PXI Systems
PXI1020 X3
LAN Server
Blade1000X1
Terminal PC
Blade100X1
GPS
LAN Server
Blade1000X1
PXI Systems
PXI1020 X3
Central Server
Enterprise250 X1
Workstations
Blade1000X2
Terminal PC
Blade100X2
IP Networks for Information Management, Condition Monitoring and Real-time Control

Figure 1

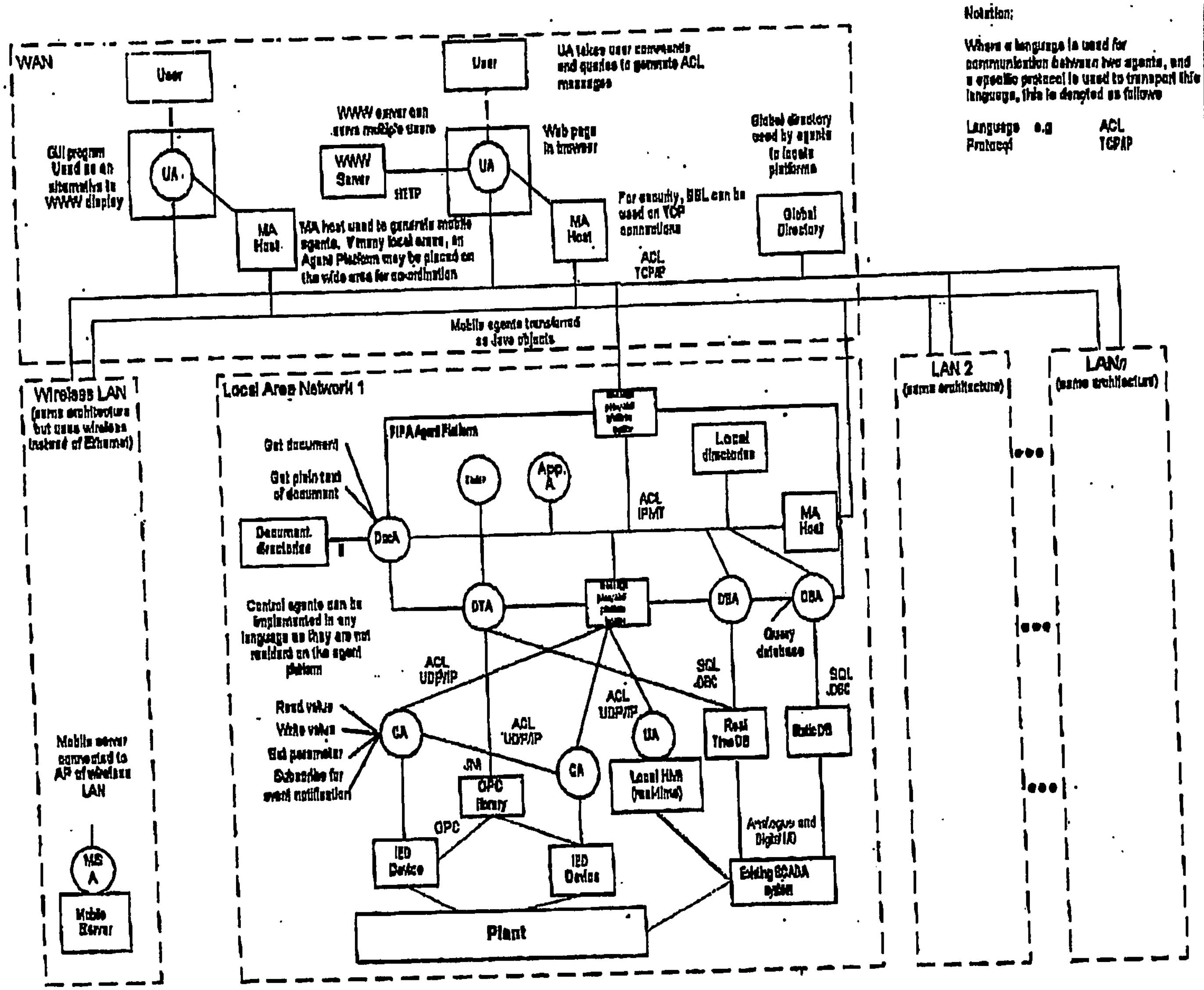
Notation:
Where a language is used for communication between two agents, and a specific protocol is used to transport this language, this is denoted as follows
Language e.g ACL
Protocol TCP/IP
WAN
User
User
UA takes user commands and queries to generate ACL messages
GUI program Used as an alternative to WWW display
UA
WWW server can serve multiple users
WWW Server
HTTP
UA
Web page in browser
Global directory used by agents to locate platforms
MA Host
MA host used to generate mobile agents. If many local areas, an Agent Platform may be placed on the wide area for co-ordination
MA Host
For security, SSL can be used on TCP connections
ACL TCP/IP
Global Directory
Mobile agents transferred as Java objects
Wireless LAN (same architecture but uses wireless instead of Ethernet)
Local Area Network 1
LAN 2 (same architecture)
LANn (same architecture)
FIPA Agent Platform
Get document
Get plain text of document
Document directories
DocA
App. A
Local directories
ACL IPMT
MA Host
DTA
DBA
DBA
Control agents can be implemented in any language as they are not resident on the agent platform
Query database
ACL UDP/IP
SQL JDBC
SQL JDBC
Read value
Write value
Set parameter
Subscribe for event notification
CA
ACL UDP/IP
ACL UDP/IP
UA
Real Time DB
Static DB
JNI
OPC library
CA
Local HMI (real-time)
OPC
Analogue and Digital I/O
IED Device
IED Device
Existing SCADA system
Plant
Mobile server connected to AP of wireless LAN
MS A
Mobile Server

Figure 2